ECE 445

Senior Design Laboratory

Project Proposal

Antweight Battlebot

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Introduction

A complete description of the Antweight battle bot that will be created for competitive applications.

Problem

Our project revolves around the Ant Weight Battle Bot competition held by Prof. Gruev. The competition is an elimination-style battle where each team's robot fights to survive 2-minute rounds against their opponent. This competition has many restrictions and requirements that introduce design challenges and considerations.

- The Battle Bot must be under 2 pounds in weight.
- Only 3D-printed parts are allowed for the chassis and weapon and can only be made out of PET, PETG, ABS, or PLA/PLA+.
- The robot is to be controlled via a Bluetooth or Wifi Enabled Microcontroller.
- The functional movement must be displayed with an indicator LED showing power is on.
- The battery voltage can not exceed 16V.
- A manual disconnect must be included for safety.
- If a pneumatic weapon is used it is limited to 250 psi. The system must also have an easily accessible bleed valve.
- Spinning weapons must come to a complete stop after 60 seconds of power disconnect.
- Finally, a custom PCB must be implemented.

Solution

For our battle bot to be competent in battle creating a strong defense would be more important than creating a glass cannon. Therefore, for our design, we decided upon a wedge-shaped bot that is as low to the ground as possible to ensure it can't be flipped over. As for a weapon, it will have a protruding lever allowing it to flip opponents that end up on top of it. This entire design will be 3D printed using PETG filament. The battlebot will be controlled through a Bluetooth controller that will send signals to the Bluetooth receiver that is found onboard the ESP32 Microcontroller. This microcontroller takes the inputs that were received from the controller and sends them to the motors that spin the wheels of the robot as well as the motor that controls the battlebot's weapon system. This will all be powered using a LIPO battery at a higher voltage that will be stepped down using a regulator for the microcontroller and its original voltage fed directly to the motors.

Visual Aid

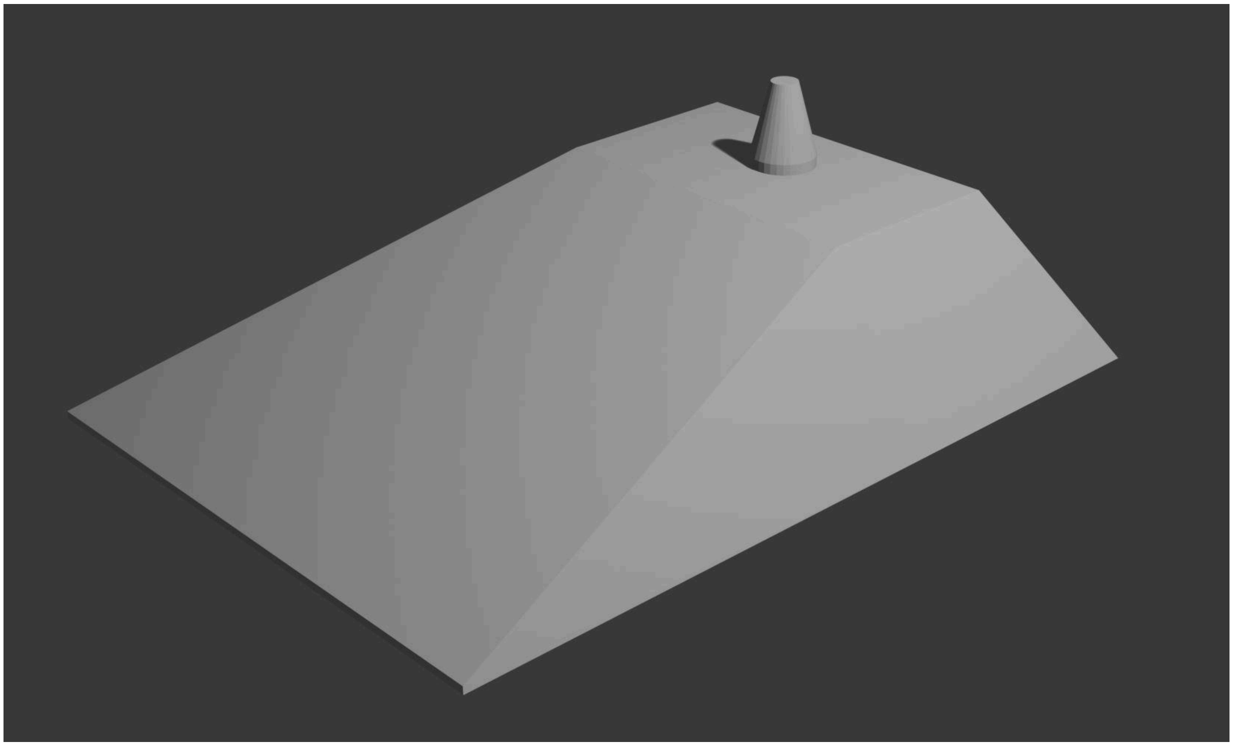

Figure 1: Battlebot Prototype

High-level requirements list

- The battle bot must not exceed 2 lbs with all required components for proper functionality. This includes motors, wheels, chassis, weapons, and onboard electronics.
- A consistent Bluetooth connection of 0.2 mbps must be established allowing for responsive movements from the input device.
- Competent movement with
    - Velocity of 4.5 feet/s
    - Wheel Rpm of 900 revolutions per minute
    - Independent bidirectional wheel movement

Design

Block Diagram

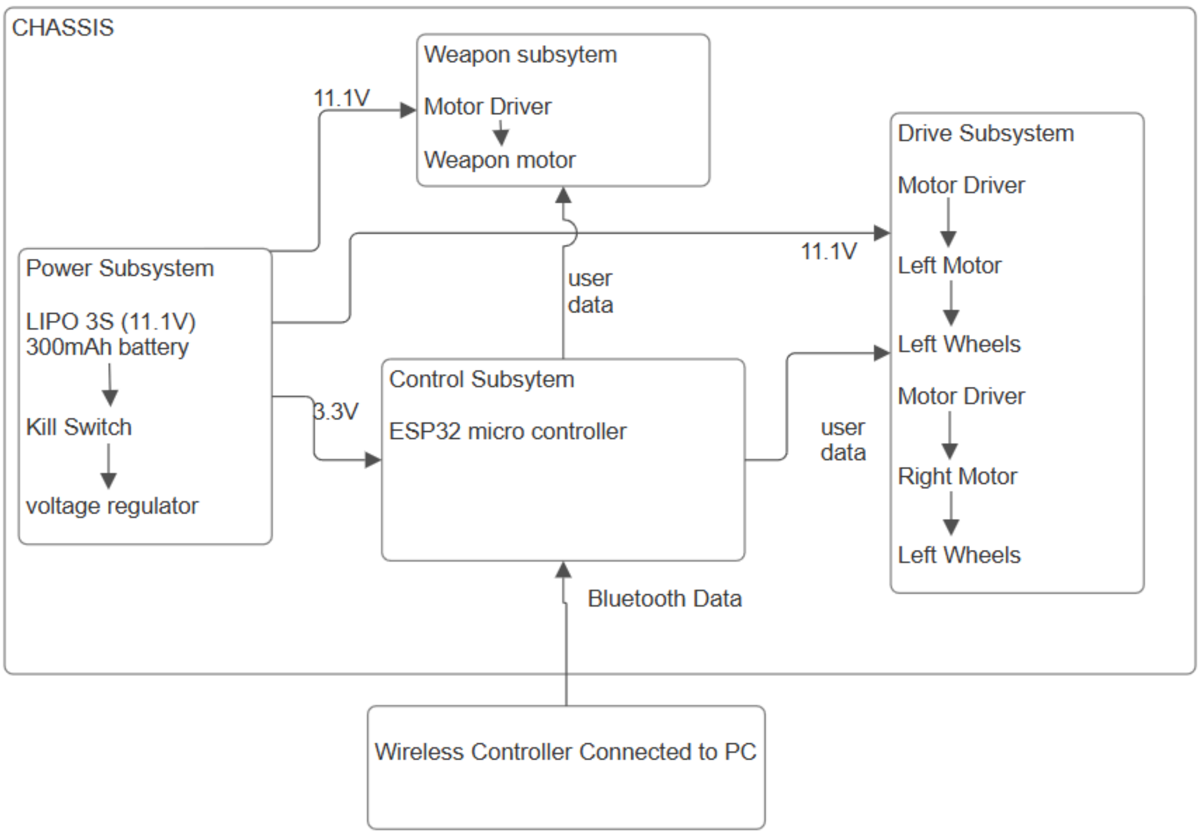

Figure 2: System Block Diagram

Subsystem Overview

1. **Chassis:** 3D printed using PETG to ensure the highest durability as we want any attack to be deflected. Although heavier it will ensure that we can create a strong chassis that can withstand attacks as well as retaliate.
2. **Drivetrain:** The battle bot is going to move using a set of 2 wheels on each side powered by 1 motor per pair of wheels. These motors are going to be connected to the wheels almost directly and the voltage will be limited to ensure correct rpm. This will allow us to choose a gear ratio that will optimize torque to the wheels while maintaining enough traction to not spin out inside of the stadium. To ensure

the robot can turn as needed the inclusion of an H bridge will allow us to control the motor's rotation in both directions.

3. **Power:** To power all the motors and the microcontroller we plan on using an 11.1V 3s LiPO battery with a capacity of 500mAh. This amount of capacity will ensure that the battle bot will be able to run for 2-3 minutes. Due to it having 3 cells and a voltage of 11.1 Volts, we can power high torque motors. We do have to add a voltage regulator to step the voltage down to 3.3V for the ESP microcontroller. This regulator will be connected to the battery through manual disconnect to satisfy the safety requirements.
4. **Control:** We plan on using an Xbox controller that is Bluetooth-connected to the microcontroller in order to control the car. This controller has its own protocols that must be followed along with the normal Bluetooth protocol. Using the onboard Bluetooth receiver found on the ESP 32 microcontroller we can follow the Bluetooth Low Energy mode standard to pair the controller.
5. **Weapon:** The 2 weapons will be the front-shaped wedge on the front of the car that forces opponents atop and then a push rod on top launches them off. The pole is moved using a motor and gear mechanism to convert the rotational force to upward motion allowing for a strong push force.

Subsystem Requirements

Chassis - since we are building a flat outer shell we have to make sure that the large surface area is not too heavy. The total weight of our robot at most can be 2 lbs which is approximately 907 grams. Ideally, our 3 printed chassis is less than 50% of the total weight. This leaves enough room for the weight of the battery, PCB, and motors that will be contained within the chassis. Due to the weight of PETG filament, we are limited to around 35 meters of this plastic material. The creation of our chassis will directly influence the mounting points of our PCB. The wheels that will be attached to the drive system are also made out of the same PETG material and must be accounted for.

- 450 grams maximum including wheel weight
- Low profile to prevent opponents from getting underneath
- At least 1.5 inches tall to allow for wheel tolerance

Drivetrain - We plan on using 4 wheels in total for our battlebot. There will be 2 Wheels on each side of the bot with a motor driving each pair of wheels. To drive the wheels we plan on using the Repeat Robotics 1406 motor, as shown in Figure 3.

- 2500kv
- 2-4s voltage
- Comes with a 5mm diameter knurled tangent drive shaft
- 13g Weight

To achieve our desired velocity of 4.5 feet/s at around 900 RPM the wheel diameter must be 1.2 inches.

- $Motor\ RPMS\ =\ 2500kv\ *\ 11.1\ V\ *\ 0.2\ *\ (5\ mm\ /(1.2\ in\ *\ 25.4)\ =\ 910.433\ rpm$
- $C\ =\ 0.6\ inches\ *\ 2\ *\ pi\ =\ 3.77\ inches$
- $3.77\ inches\ *\ 910.433\ rpm\ =\ 3432.33\ inches/minute$
- $V\ =\ 3016\ inches/minute\ /\ (12\ inches\ *\ 60s/minute)\ =\ 4.76713\ feet/s$

The final calculated speed will be 0.267 feet/s faster which only equates to around 5% more speed than we want. This is fine because this is assuming ideal speed and real-world factors like the inertia of the wheels will slow the actual speed of the wheels down.

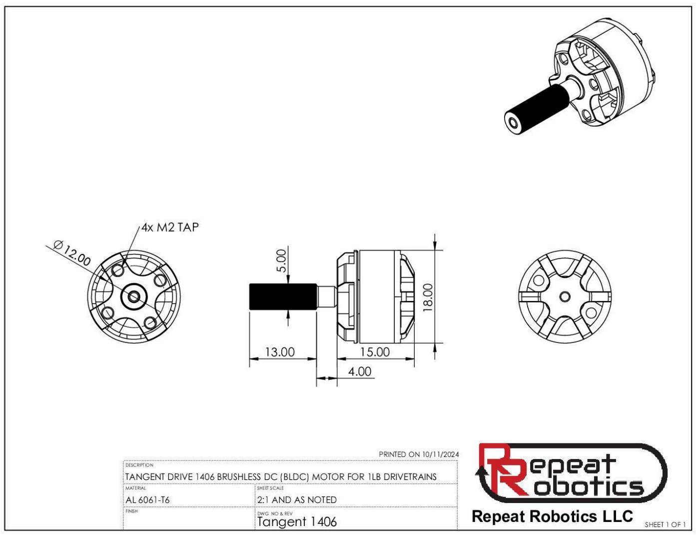

Figure 3: Repeat Robotics 1406 Motor

The motor driver that is going to be used is the MCF8315D 40 pin (Figure 4) from Texas Instruments. This driver IC is chosen for its ability to work with brushless DC motors and works with voltages ranging from 4.5V to 40V. The driver also allows for reverse, discarding the use of an external H bridge, and has advanced speed control using PWM.

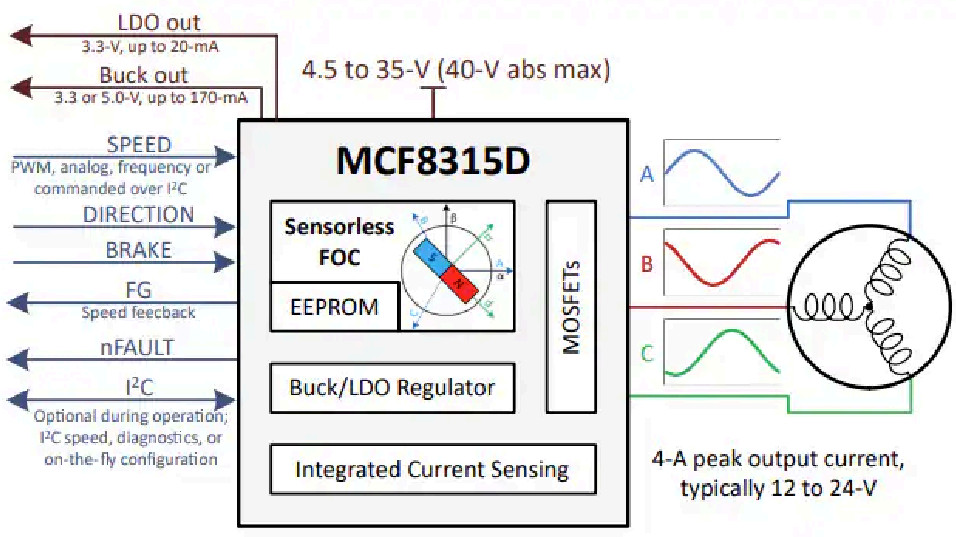

Figure 4: MCF8315D Chip Overview

Power - The power distribution for all the motors and the microcontroller will be handled in this subsystem. We will be using an 11.1V 3s LiPO battery which is commonly used for robotics and RC applications.

- 11.1V peak voltage
- 500 mAh capacity
- 35c continuous discharge with a peak discharge of 70c
- 47g weight

This battery will be connected to a manual disconnect through a JST plug as the battery is already terminated in a male JST connection. Due to the microcontroller operating at 3.3V with a minimum operating current of 0.5 Amps, we have to add a voltage regulator to step the voltage from the battery down to 3.3 V. This will be done by the LM317T adjustable voltage regulator found in the supply center.

- Minimum output current of 1.5 A
- Adjustable voltage range of 1.2 V to 37 V

Control - To control all the robot motors, we will use an ESP32-DOWD-V3 (Figure 5) because of wifi/Bluetooth capabilities, low power consumption, and high level of integration. The 4 Mbps Bluetooth capability will be used to control the motors from a PC and an XBOX controller, which is more than enough for our 0.2 Mbps requirement. The ESP32 has various GPIO pins of which 3 will be used to control the 2 motors for the wheels and another for the motor used in the weapon. ESP32 requires a 3.3V power source which has already been addressed in the power section and the ESP32 also has connections that work well with the MCF8315D motor drivers such as the clock and various sensor inputs. The ESP32 also features internal memory for core functions and SRAM for data and instructions. The ESP32 consumes about 240mA of power when on but that can increase up to 790mA when both wifi and Bluetooth are used simultaneously. This power consumption is within range when compared to equivalent chips and a variety of sleep modes exist when less consumption is required. Finally, for debugging purposes, an ESP32 development board is sold in the ECE supply shop which will be purchased to begin development of the motors and motors drivers without the need to solder an ESP32 chip onto the PCB.

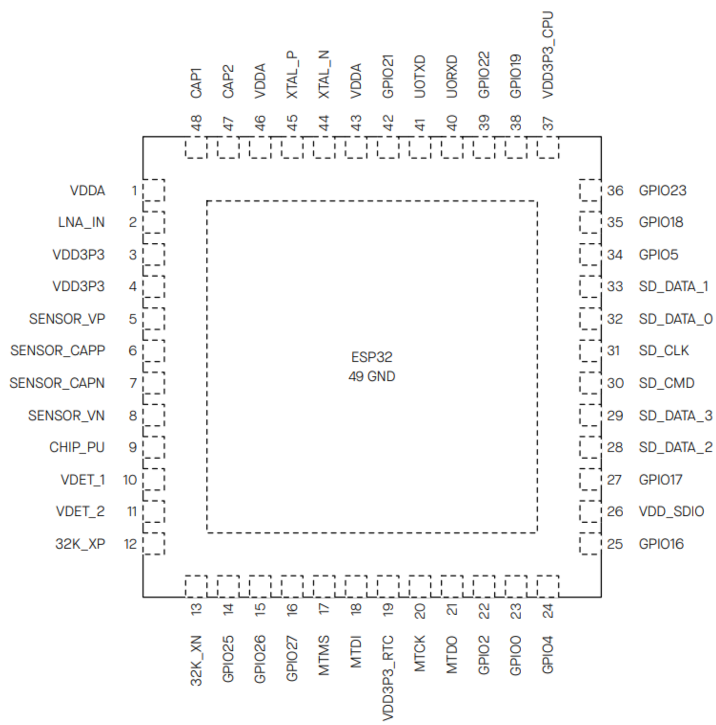

Figure 5: ESP32-DOWD-V3

Weapon - The battle bot will feature two primary attack mechanisms:

1. Front Wedge – A sloped wedge at the front of the bot designed to get underneath opponents and destabilize them.
2. Launch Rod – A vertically actuated rod that extends from the top of the bot to launch or dislodge opponents that climb on top.

The front wedge will be angled at 30 degrees, optimizing its ability to slide under opponents and lift their wheels off the ground, reducing their traction and mobility. This design uses leverage to disrupt enemy control and get them above our car to potentially tip them over. The wedge will be reinforced to withstand repeated impacts while remaining lightweight.

The launch rod mechanism operates as illustrated in Figure 6, where a brushless motor drives a gear system that converts rotational motion into linear motion. This allows the rod to extend upward when engaged and retract back to a flush position with the top of the bot when idle. A spring-loaded return mechanism ensures that the rod returns to its starting position automatically.
The rod will be designed to match the diameter of the wheels, ensuring that when fully retracted, it remains level with the bot's top surface, preventing unintended obstructions. To optimize performance, a brushless motor is selected for its high torque-to-weight ratio and rapid response time, ensuring the rod's quick and forceful deployment. The rod and gear assembly will be 3D printed using PETG to provide a balance of lightweight durability and impact resistance, which is critical for maintaining effectiveness in combat scenarios.

- 1100kv brushless motor
- 7.4-15V operating voltage
- 52g
- 866g pull weight

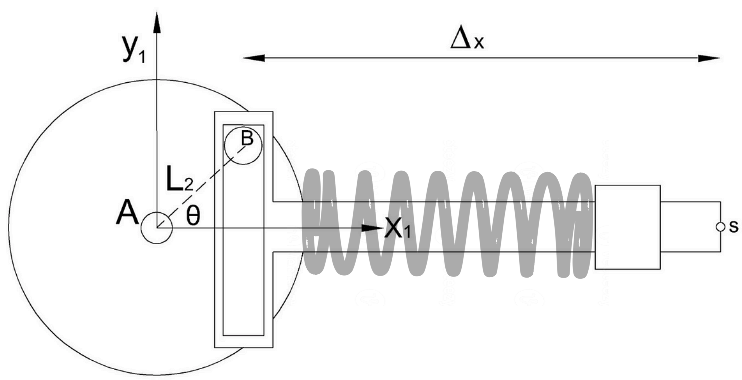

Figure 6: Rod Attack Mechanism

Tolerance Analysis

Energy Consumption - A bottleneck that is crucial to the success of our project is ensuring that the Li-Po battery can satisfy the energy requirements of our battlebot for the duration of the battle itself. Battlebot battles typically last about 2 minutes. The Li-Po we are using can provide 500 mAh of energy before needing a recharge.

- The ESP32 can consume upwards of 790 mA when the Bluetooth receiver is enabled.

- Each of the motors used for turning the wheels will consume a maximum of 8,000 mA per the datasheet.

- The motor used for the weapon has an unknown current consumption. However, based on estimates for peak power consumption of 185 W and a max battery voltage of 11.1 v we would draw 16.6 A of current
- $Max\ operating\ time\ at\ peak\ draw\ =$
  $\frac{500\ mAH}{790\ mA + 2*8{,}000\ mA + 16600\ mA} \times \frac{60\ minutes}{1\ H} = 0.89\ minutes$

This is a hypothetical Maximum runtime if the battle bot is driving constantly and the weapon is operating constantly. In reality, the weapon will only be used when near enemies and the motors driving the wheels will not operate at full power, consuming well over 30,000 mA, at all times. We will need to keep this limit in mind though and may need to consider batteries that can store more energy or motors that consume less energy. However, when operating the Battle bot we will not be running the motors at peak power. Instead, we will reduce the throttle limit to 20% to avoid wheel slippage. Due to this limit being applied to the motors we expect they will only consume 2.2 A at peak. The weapon motor will run at 11.1 V to reduce its current draw while also only running at 40% of its max power rating. This will ensure that the 500 mAh battery is sufficient for our battle applications.

- $Theoretical\ continuous\ current\ draw\ =$
  $2.2A\ +\ 2.2A\ +\ 6.6A\ +\ 790mA\ =\ 11856.7\ mA$
- $Theoretical\ operating\ time\ =$
  $\frac{500\ mAH}{790\ mA + 2*2{,}200\ mA + 6600\ mA} \times \frac{60\ minutes}{1\ H} = 2.53\ minutes$

We also have to take into consideration the C rate of our battery along with the C rate we will expend for the entire system. Our battery has a continuous C rating of 35C and a max rating of 70C. When drawing peak current our system requires 33456.7 mA / 500 mA = 66.91 C which is less than the max 70 C rating of our battery. Based on our throttled continuous use estimations, we will only need 11856.7 mA/ 500 mA = 23.7 C which is also less than the rated 35 C for continuous use.

Ethics and Safety

Ethics - In designing and building a battlebot there are several ethical concerns that must be addressed. In accordance with section 1.1 of the IEEE Code of Ethics, we will ensure that the safety, health, and well-being of us and our community are paramount. We will disclose any and all dangers to the public and the environment. Fortunately, our battlebot will be designed to work indoors so we aspire to have minimum impact on the environment. However, our battlebot and other battlebots are designed to operate in the presence of people making safety a high priority. In addition to section 1.1, we will adhere to section 1.5 of the code of ethics by listening to technical feedback and adjusting our design accordingly. We will be honest about our technical limitations. For instance, in designing a battlebot we will need a motor drive for the wheels with which we do not have substantial design experience. We will research the proper way to implement the system and do so correctly while at the same time maintaining a level of honesty with each other and our professors and teaching assistants. We will not make unsubstantiated claims and ensure design decisions involve grounded analysis whether mathematical or in simulation.

Safety - A small, highly mobile battlebot powered by a Li-Po battery can pose multiple dangers. Misuse or mishandling of Li-Po batteries can result in rapid discharge which can lead to fires, smoking, and thus toxic smoke inhalation. In accordance with Code 1 of the IEEE Code of Ethics, we will ensure to follow common safety practices to ensure that we handle the Li-Po batteries with care to avoid fire, or short-circuiting which could endanger us or the community. For one, we will always charge the Li-Po batteries with the appropriate charger away from flammable materials. When powering the BattleBot we will place the robot in a nonflammable container. This will ensure that a fire is contained as well as that the robot is contained in the case of a short circuit or if the robot operates unprompted. While the robot is charging or in a state of operation we will ensure that one of us is always nearby to neutralize any potential dangerous situation. Testing the robot in an enclosed structure will also allow for safe testing of our motorized weapon. A motorized weapon operating at a high rpm can pose a serious danger if a piece flies off during operation. To ensure this does not occur we will first test our weapon within an enclosure which could protect against the danger of a flying projectile. For our project we do not anticipate the need for potentially dangerous chemicals or biological materials so fortunately our safety concerns rely mostly on proper mechanical and electrical safety.

References

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